DOCUMENT RESUME

ED 050 162 TM 000 555

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TITLE	Inductive Reasoning Processes in Concept Learning
INSTITUTION	Texas Univ., Austin.
SPONS AGENCY	Department of Defense, Washington, D.C. Advanced Research Projects Agency.
PUB DATE	Feb 71
NOTE	24p.; Paper presented at the Annual Meeting of the American Educational Research Association, New York, New York, February 1971
EDRS PRICE	EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS	Cognitive Ability, *Cognitive Processes, *Concept Formation, Factor Analysis, Factor Structure, Feedback, *Inductive Methods, Models, *Performance Factors, Success Factors, *Task Performance, Testing Problems, Test Validity, *Vocational Rehabilitation

ABSTRACT

Traditionally, studies investigating the relationship between mental abilities tests and performance on learning tasks have attempted to establish a direct relationship between these two domains by use of factor analytic techniques. It is suggested that an alternative approach can be formulated in terms of an information processing analysis of both the test and the task. Two experiments, undertaken to examine the use of intellectual process constructs in considering this relationship, are fully described. According to the proposed model, the first stage would be an information processing analysis of known tests of mental ability. The results of Experiment I indicate that commonly-used tests of mental abilities may be composed in part of several specifiable intellectual processes which may be similar across a diverse range of mental abilities. Experiment II revealed that instructing a group of subjects to use hypotheses relevant to attaining solutions in a series of concept problems contributed significantly to their mean performance. In addition, hypothesis generation, evaluation, and memory are proposed as three intellectual processes important in concept learning problems. (Author/PR)

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Inductive Reasoning Processes in Concept Learning*

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Traditionally, studies investigating the relationship of tests of mental abilities to performance on learning tasks have attempted to establish a direct relationship between these two domains by use of various factor analytic techniques. Generally, two types of approaches have been used in studies of mental abilities and learning: (a) One approach has been to factor analyze both tests of mental abilities and measures of learning task together; (b) The second approach is to determine the factor structure for tests of mental abilities and then to extend the learning measures into this structure. In both approaches, factor loadings on specific factors are interpreted as being indicative of the relationship between mental abilities and performance on a learning task. If an Ability A has a stronger relationship to performance on a learning task than an Ability B, this is usually interpreted as implying that Ability A is utilized more than Ability B in attaining solution of a learning task.

An alternative approach to the interpretation of the relationship between mental abilities and performance on a learning task can be formulated

*Presented at the annual meeting of the American Educational Research Association, New York City, February 4-6, 1971.

This research was supported by Advanced Research Projects Agency Contract No. N00014-67-A-0126-0006.

in terms of an information processing analysis of both the tests of mental abilities and the learning task. Let us assume that an information processing analysis of tests of mental abilities would reveal that most tests commonly used to define an ability contain several specifiable intellectual processes. Let us further assume that an analysis of the learning task would yield similar results. This then would imply that the relationship between mental abilities and performance on a learning task is a function of the similarity of the common intellectual processes that must be employed for successful performance on both the mental ability tests and the learning task. Therefore, the greater the similarity of the intellectual processes _S_ must utilize to perform successfully on a mental ability test to the intellectual processes necessary for attaining the correct solution of a learning task, the stronger the measured relationship between that mental ability test and performance on a learning task. For example, mental ability tests such as Induction and General Reasoning, which have been shown to be strong contributors to performance on a learning task (Dunham, J. L., & Bunderson, C. V., 1969), may be thought of as a series of concept learning problems. In general, tests of these mental abilities require the _S_ to form a concept and then to determine if a particular stimulus configuration is or is not an examplar of the concept. The difference between these tests and concept learning tasks is that generally feedback is not supplied in tests of mental abilities. It is not surprising then to find that these tests, which require intellectual processes highly similar to those of the concept learning task, are found to be strongly related to performance on the concept learning task.

If a domain of intellectual processes could be established, it should provide an adequate description of an _S_'s performance on both tests of mental abilities and learning tasks. It would appear then that this new domain of intellectual processes would provide relevant information as to the meaning of the relationship between mental abilities and performance on a learning task.

As is often the case in the field of psychology, the easier task is that of describing what may appear to be useful constructs, rather than the formulation of specific experimental techniques designed to evaluate the usefulness of such constructs. An attempt will be made to formulate a model with specific references to the necessary methodological considerations needed to construct a domain of intellectual processes. The initial outline of the model will be in terms of the mental ability of Induction; from this outline a generalized model for the study of the relationship between mental abilities and performance on a learning task will be formulated.

The first stage in an investigation of the relationship between the mental ability of Induction and performance on a concept learning problem in terms of common intellectual abilities would be an information processing analysis of the known tests of Induction. Analyzing several tests of Induction with respect to the processes _S_ must execute to attain a satisfactory score on the ability test provides the experimenter with several rationally isolated intellectual processes. Tests could then be constructed to measure each of these hypothesized intellectual processes. These tests should be constructed so as to be as similar as possible to the content material of the original ability test and a measure of a single intellectual process relevant to that ability test.

A similar information processing analysis of the concept learning task should be undertaken. Tests of intellectual processes relevant to attaining solution of the concept learning task could also be constructed. This type of analysis of the learning task provides the experimenter with information regarding the nature of the information processing requirements of the task. Knowing the information processing requirements of the task enables the experimenter to make decisions regarding the possible effect of different experimental manipulations upon the learning task. This provides a rational basis for predicting the results of different experimental manipulations. Experimental manipulation of variables affecting the hypothesized intellectual processes utilized by Ss is also a powerful technique to aid in the establishment of construct validity.

If the tests constructed from an information processing analysis of both the mental ability tests and the learning task were factor analyzed together, the resulting factors would be the intellectual processes common to the Induction ability and the concept learning task. This procedure is depicted schematically in Figure 1. If this same procedure were expanded to include a wide range of mental ability tests and diverse learning tasks, it would then be possible to establish a domain of intellectual processes that are common to mental ability tests and learning tasks.

Insert Figure 1 about here

There are several advantages that can be gained by using measures of intellectual processes rather than tests of mental abilities: (a) It may be possible to reduce the rather large domain of mental abilities to a relatively small number of intellectual process measures; (b) Intellectual processes obtained by factor analysis can be used in experimental studies in the same way that conventional ability measures are now used, but with greater expectation of interpretation and generalizeable results; and (c) Mathematical models of learning can be formulated using the constructs of intellectual processes which would allow the investigation of the role of individual difference parameters in the solution of concept learning problems.

Information processing models could be constructed utilizing constructs from the domain of intellectual processes. If such a model of concept learning was formulated, scores for individual Ss on various intellectual processes could be utilized to predict performance on various concept learning problems. This would then provide an important tool for the study of individual differences in concept learning problems. Such a model cannot be formulated adequately until the domain of intellectual processes has been established. For the purpose of discussion, a general hypothetical flowchart of an information processing model is depicted schematically in Figure 2. If a model were constructed from such a flowchart and measures were available for such processes as generation of hypotheses, selection of a single hypothesis, storage of hypotheses and evaluation of hypotheses, then predictions of individual performance on concept learning problems could be formulated.

Insert Figure 2 about here

Two experiments were undertaken to examine the use of intellectual process constructs in the investigation of the relationship of mental abilities to performance on concept learning tasks. According to the proposed model the first stage in such an investigation would be an information processing analysis of known tests of a mental ability.

EXPERIMENT I

This study was an attempt to investigate the concept that known mental ability tests are composed of specifiable intellectual processes. The general approach was to examine the known tests that define the mental ability under consideration, with respect to the intellectual processes S must perform in order to attain an adequate score on that ability. In the present study, such an analysis of the induction factor was undertaken. Induction was chosen for two reasons: (a) It logically appears that induction would be an important aspect of concept-learning performance. Understanding the nature of induction should provide useful information about the cognitive processes relevant to concept-learning, and (b) Previous research (Dunham & Bunderson, 1969) shows that induction relates strongly to performance on concept learning tasks across different treatment groups and that these groups cannot be discriminated on the basis of the induction ability.

The French Kit of Reference Tests for Cognitive Factors (French, et al, 1963) defines induction primarily by two tests: Location Test and Letter Sets. With respect to the cognitive processes that S must perform, a preliminary information processing analysis of these two tests revealed three hypothesized intellectual processes: evaluation, hypothesis generation, and memory for the generated hypothesis. Two tests for each of the hypothesized intellectual processes were constructed. In this study, it was predicted that the three hypothesized intellectual processes would show a strong relationship to known tests of Induction and to several other tests of mental abilities.

Subjects. The Ss were 118 male and female students from a community college in Waco, Texas. Elimination of 43 Ss who failed to complete all the materials decreased the sample size to 75.

Tests. A battery of five ability tests from the Kit of Reference Tests for Cognitive Factors (French, et al, 1963) was administered to all Ss. They were: Locations (I), Letter Sets (I), Ship Destination (R), Object-Number (Ma), and Hidden Patterns (Cf).

Two tests from Guilford's Structure of Intellect Model were included: Letter Classification (CSC) and Multiple Grouping of Nonsense Words (DSD).

In addition, all Ss were administered two tests for each of the hypothesized intellectual processes: hypothesis generation, evaluation, and memory. The hypothesis generation-(1) test contained one item, and S was instructed to list as many rules that could apply to this item as possible. The hypothesis generation-(2) tests required S to construct items similar to the item presented. The measure of memory-(1) required S to study several rules, each of which had a number associated with it. After studying the rules and their associated numbers, S was instructed to turn to a test page containing 10 items. His requirement was to respond to each item with the number of the rule that could be applied to that item. Memory-(2) required S to study a page with groups of nonsense words. Each of these groups formed a class. On the test page, S was presented with groups of four words per group and was required to choose one of the four words from each group that was in one of the classes he had just studied. The measure of evaluation-(1) consisted of a rule followed by several items. The S was instructed to respond as to whether or not each item was an example of the rule. Evaluation-(2) consisted of several items followed by five rules. The S was required to determine which rules pertained to the given items.

Procedure

Administration of the tests required three hours, divided into sessions of one hour each on three different days. The mental ability tests were administered in the first two sessions, and the intellectual process tests were administered in the last session.

Results

The six intellectual process tests were intercorrelated and factor analyzed by the principal-axis method. Three factors were extracted and rotated to a Varimax criterion. The rotated factor matrix appears in Table 1. The three hypothesized factors of hypothesis generation, evaluation, and memory were clearly defined.

Insert Table 1 about here

The multiple R's obtained by using the three factor scores as predictors for each of the seven mental ability measures are reported in

Table 2. The largest multiple R was found when performance was predicted on the Location Test measure of Induction.

Insert Table 2 about here

Discussion

The factor analysis revealed three factors which coincided with the hypothesized intellectual processes of evaluation, hypothesis generation, and memory. The high mulitple R's for the Induction tests, using only the factor scores as predictors, seem to imply that the hypothesized intellectual processes may, in fact, adequately describe the processes needed to account for performance on tests such as letter sets and Locations. Measures for mental abilities, such as General Reasoning, Associative Memory, and Flexibility of Closure, were included to determine whether measures of intellectual processes would have a relationship with tests other than those of Induction. The multiple R's for these tests, although generally not as high as those for Induction, suggest that other mental ability tests may also have similar specifiable intellectual processes.

The two tests from Guilford's Structure of Intellect Model are tests of cognition for semantic classes and divergent production of semantic classes. These factors have been shown to have a strong relationship to certain types of concept problems (Dunham, J. L., Guilford, J. P., & Hoepfner, R., 1968). Letter Classification strongly defines the CSC factor, while Multiple Grouping of Nonsense Words is a strong contributor to the DSC factor. The multiple R's for these tests also imply that individual variation on ability tests may be, in part, a function of individual differences with respect to some specifiable intellectual processes.

A preliminary investigation of this type is not offered as conclusive evidence that mental abilities are composed of specifiable intellectual processes. It does, however, suggest that across a diverse range of mental abilities, there is a substantial relationship between mental abilities and measures of intellectual processes. This then implies that in studying the relationship between mental abilities and performance on concept learning tasks it may be unnecessary to administer large batteries of mental ability tests. The behavior described by a battery of mental ability tests may be just as adequately described by a few measures of intellectual processes. If this is the case, then mental abilities could be understood in terms of their intellectual processes, and theories of concept learning could be formulated that described performance as a function of several intellectual processes. This would then allow the investigation of individual difference parameters within a concept learning model.

EXPERIMENT II

The results of experiment I indicate that commonly used tests of mental abilities such as Induction may in part be composed of several specifiable intellectual processes and that these processes may be similar across a diverse range of mental abilities. The second stage in attempting to establish a domain of intellectual processes is an information processing analysis of the concept learning task to be used with respect to the intellectual processes that a subject may utilize in attaining solutions.

An information processing analysis of several learning tasks revealed that concept learning tasks in which the dimensions of the task are specified to Ss has the effect of limiting the number of possible hypotheses with which the Ss must consider. If such experiments are concerned with the processes relevant to the induction of a class concept, then limiting the number of possible hypotheses lessens the role of processes necessary to the generation of hypotheses. In this experiment, the concept learning task was constructed such that the dimensions were not previously specified and therefore would not restrict the number of possible hypotheses.

It was hypothesized that these concept learning problems with unspecified dimensions can be solved by forming hypotheses about the correct solution and then evaluating these hypotheses with respect to other instances of the concept. The Ss must form and then use these hypotheses to attain the correct concept. Since these intellectual processes were similar to those found in the mental ability of Induction, new tests were not constructed. Instead the same tests used to measure hypothesis generation, evaluation and memory in experiment I were incorporated in this study. It is important to realize that in terms of the model proposed this has the effect of implying that the three hypothesized intellectual processes are the processes common to both the mental ability test of Induction and the concept learning task. In the proposed model these common intellectual processes would be determined by factor analysis of tests constructed from the mental ability test and from the concept learning task.

It has been demonstrated previously that Induction is a strong contributor to performance in concept learning tasks for different treatment groups (Dunham & Bunderson, 1969). It appears plausible to hypothesize that the intellectual process measures will have a strong relationship to performance and, also, that these measures will be differentially related under different experimental manipulation of the learning task. Further, it appears that these relationships could be predicted from a knowledge of the information processing restraints caused by a given experimental manipulation. It was hypothesized that different experimental treatment manipulations, such as the availability of possible hypotheses, would alter the relationship between performance on the concept learning problems and the intellectual process measures.

Method

Subjects. The Ss were 118 male and female students from an introductory educational psychology class at The University of Texas at Austin.

Tests. The tests for experiment II were the same as those used in experiment I: two tests for each of the three hypothesized intellectual processes were administered to all Ss.

Problems. Eight concept learning problems, each consisting of 32 instances, were given to all Ss. Each instance consisted of a series of letter sets each containing four capital letters. The type of concepts to be learned were: a repeated letter, the letter X, an initial vowel, and letters in some form of alphabetic order. The presentations were organized in the form of a teaching booklet, so that one page presented the instance, the next page repeated the instance with the correct feedback. The Ss were instructed to respond yes or no to each instance.

Procedure. Administration of tests and learning tasks required three hours, divided into two sessions of one and one-half hours each on two different days. The process measures were administered in the first session, and the learning task was administered in the second session. The Ss were randomly assigned to two groups, a hypothesis supplied (HS) group of 57 Ss and a no-hypothesis supplied (NHS) group of 61 Ss. Each group was presented with the same eight concept problems, in the same order. The Ss were given 3-1/2 minutes per problem at the end of which both groups were shown five possible hypotheses, one of which was the correct solution to the concept problem, and were instructed to record their choice for the correct solution in the answer booklet. Both groups received the same instruction regarding the nature of the stimuli, the nature of the task, and the response recording procedures. At the end of each problem, both groups were shown the five possible hypotheses. However, for the first four problems, the HS group received the five possible hypotheses with additional instructions regarding their use in helping to solve the concept problem. The presentation of the last four problems was identical for both groups.

Results

The six process tests were intercorrelated and factor analyzed by the principal-axis method. Three factors were extracted and rotated to a Varimax criterion, yielding the hypothesized factors, hypothesis generation, evaluation, and memory. The rotated factor matrix appears in Table 3.

Insert Table 3 about here

For the purposes of analysis, only the total number of errors on the first four problems and the total number of errors on the last four problems were used. The source table for the analysis of variance of the number of errors is reported in Table 4. The results of the analysis of variance on the number of errors as the dependent variable revealed a significant main effect for the hypothesis conditions ($p < .01$) and a significant interaction between problems and hypothesis conditions ($p < .01$). Both of these effects were due mainly to the superior performance of the HS group on the first four problems.

Insert Table 4 about here

On the basis of an analysis of the intellectual processes involved in the solution of the concept learning task, it should be possible to discriminate the Ss who solved the first four problems and Ss who solved the last four problems in the two hypothesis conditions on the basis of the intellectual abilities of hypothesis generation and evaluation.

Within both conditions the groups were divided into solvers and non-solvers on the basis of eight consecutively correct responses for both the _S_s attaining correct solutions for the first four problems and the last four problems. The discriminant function for Problems 1 through 4 was significant beyond the .01 level, while Problems 5 through 8 approached significance ($p = .06$). The correlations between the discriminant scores and the factor scores for evaluation, hypothesis generation, and memory for _S_s attaining the correct solution are reported in Table 5. The correlations between the discriminant scores and hypothesis generation factor scores for Problems 1 through 4 were high positive while those for evaluation and memory were either lower or negative. For the last four problems, the correlation of hypothesis generation and memory factor scores with the discriminant scores were either negative or lower than the high positive correlations of evaluation.

Insert Table 5 about here

Discussion

Instructing a group of _S_s to use hypotheses relevant to attaining solutions in a series of concept problems did contribute significantly to their mean performance when compared to a group that was not given the hypotheses.

Three intellectual processes were hypothesized to be important in concept learning problems: hypothesis generation, evaluation, and memory. In order to solve the type of concept problem used in this study, hypotheses about the correct solution must be formed and then evaluated with respect to other instances of the concept.

The availability of possible hypotheses should minimize the role of the intellectual process of hypothesis generation and place a greater emphasis on the role of evaluation of the given hypothesis. In the NHS condition, the Ss must generate their own hypotheses about the nature of the solution, thereby placing a greater emphasis on the intellectual process of hypothesis generation.

The results suggest that Ss attaining solution in the two conditions for Problems 1 through 4 and for Problems 5 through 8 had different intellectual ability profiles. This was supported by the discriminant analysis on Ss who attained solution in the two conditions. In Problems 1 through 4, Ss who solved were high on hypothesis generation and low on evaluation and memory, while for Problems 5 through 8, Ss who solved were high on evaluation and low on hypothesis generation and memory.

The results of these two studies indicate that the use of common intellectual processes in the study of the relationship of mental abilities to concept learning problems is a viable approach. Three processes common to both the Induction ability and concept learning task were isolated and tests of each constructed. Factor analysis of these tests revealed factorial validity of the hypothesized constructs which were replicated across studies. It was shown that the process measures predicted performance on a diverse range of mental ability tests, more importantly the relationship of these constructs to performance under different experimental manipulations were predictable from a knowledge of the information processing constraints of the task. A study is currently being undertaken to determine if the relationship of intellectual processes will generalize to concept learning tasks with different types of stimulus material.

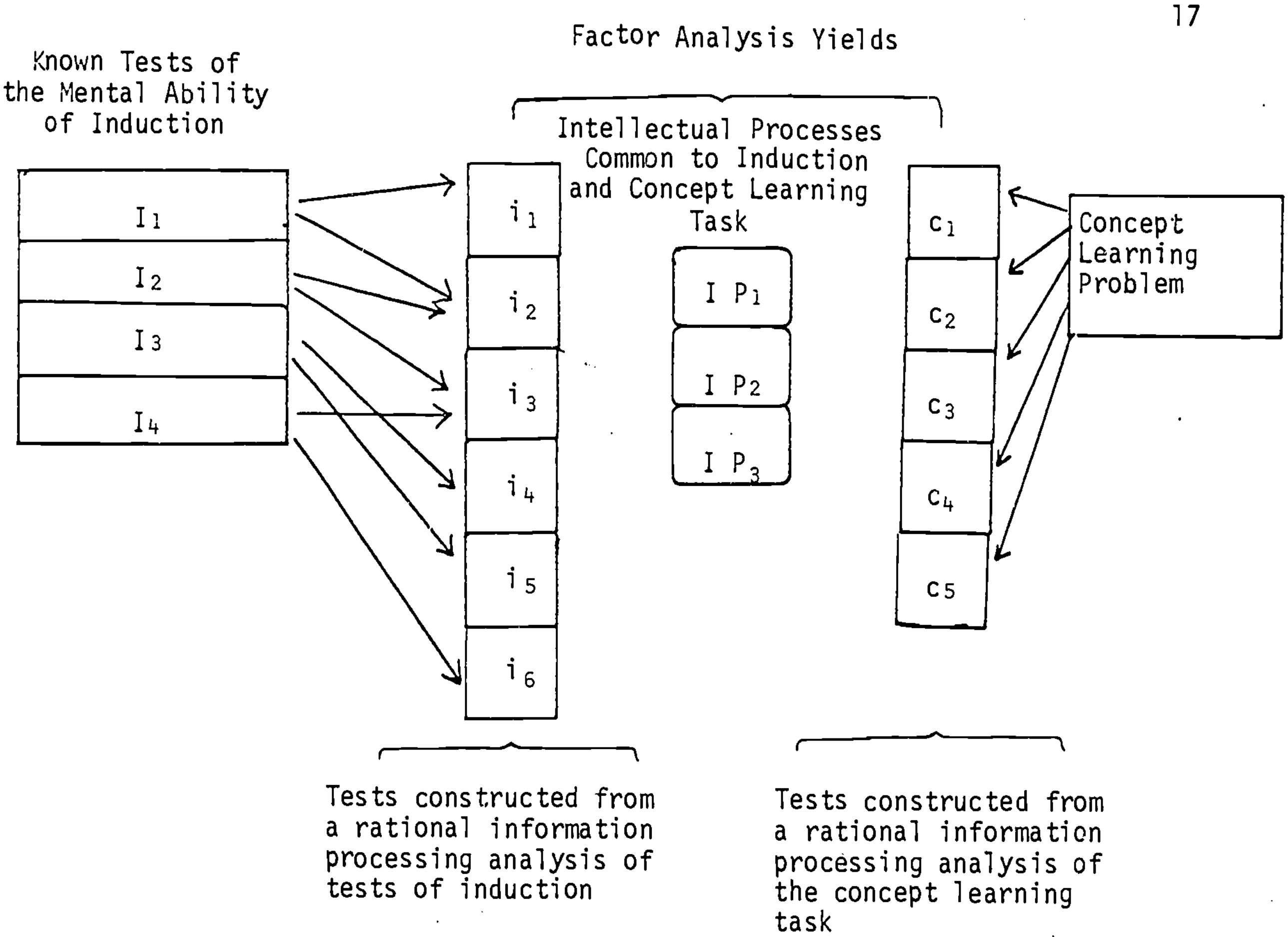

Figure 1

An example diagram of an approach for the investigation of intellectual processes common to mental ability tests and learning tasks.

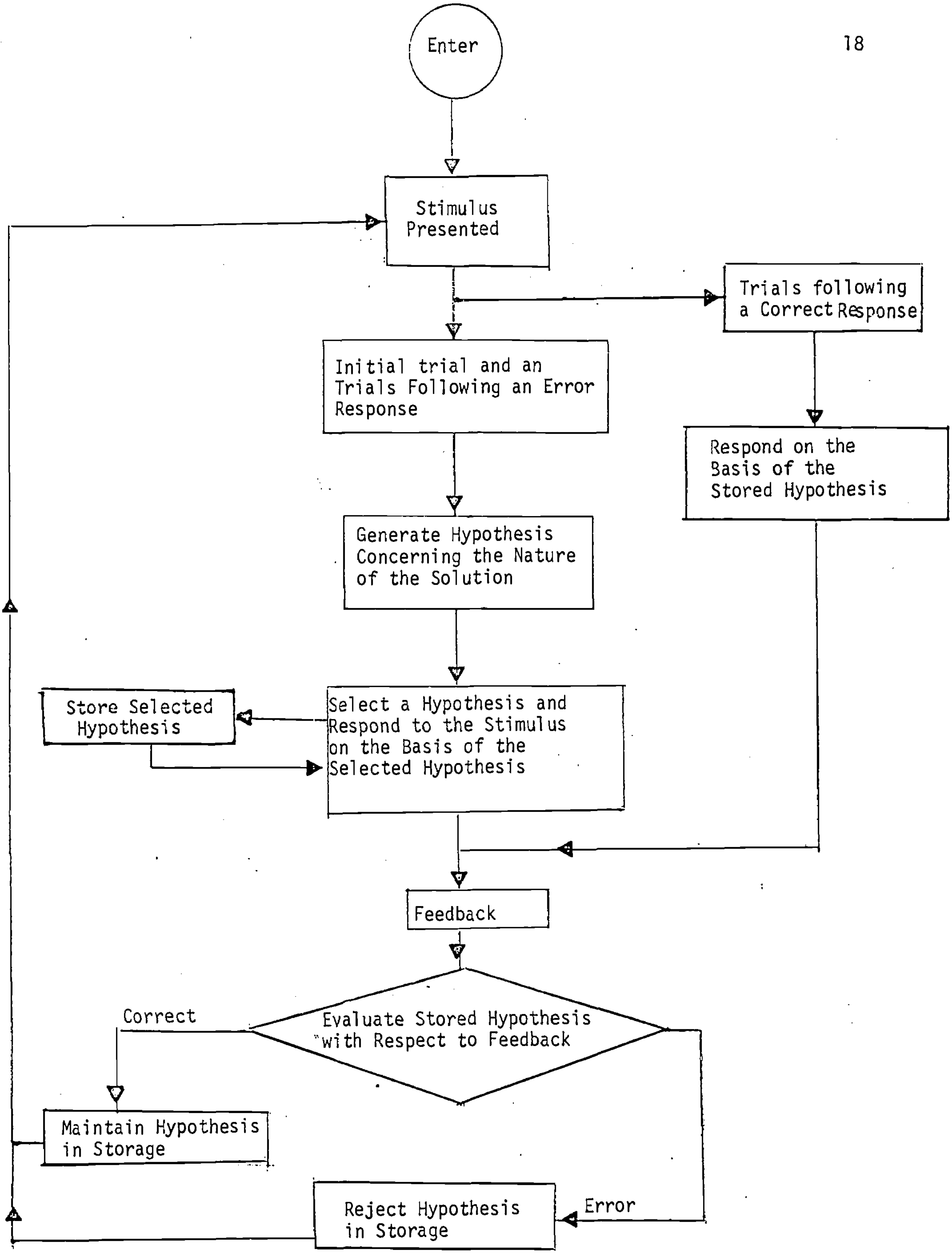
Enter
Stimulus Presented
Trials following a Correct Response
Initial trial and an Trials Following an Error Response
Respond on the Basis of the Stored Hypothesis
Generate Hypothesis Concerning the Nature of the Solution
Store Selected Hypothesis
Select a Hypothesis and Respond to the Stimulus on the Basis of the Selected Hypothesis
Feedback
Correct
Evaluate Stored Hypothesis with Respect to Feedback
Maintain Hypothesis in Storage
Error
Reject Hypothesis in Storage

Figure 2

Table 1

Rotated Factor Matrix

Tests	Factors		
	Evaluation	Hypothesis Generation	Memory
1. Hypothesis Generation-1	.36	.85	.09
2. Hypothesis Generation-2	.16	.69	.42
3. Evaluation-1	.81	.28	.38
4. Evaluation-2	.89	.26	.22
5. Memory-1	.30	.11	.87
6. Memory-2	.27	.48	.65

Table 2

Multiple Correlation Coefficients

Tests	Predictors
	Factor Scores
1. Locations (I)	.46
2. Letter Sets (I)	.73
3. Ship Destination (R)	.47
4. Object-Number (Ma)	.40
5. Hidden Patterns (Cf)	.60
6. Letter Classification (CSC)	.68
7. Multiple Grouping of Nonsense Words (DSC)	.66

Table 3

Rotated Factor Matrix

Tests	FACTORS		
	Evaluation	Hypothesis Generation	Memory
1. Hypothesis Generation-1	.17	.69	.25
2. Hypothesis Generation-2	.14	.84	.03
3. Evaluation-1	.88	.10	.25
4. Evaluation-2	.85	.27	.13
5. Memory-1	.24	.17	.73
6. Memory-2	.11	.09	.83

Table 4

Analysis of Variance of Total Number of Errors in the First and Last Four Problems for Two Hypothesis Conditions

Source	df	MS	F
Between Ss	117		
Hypothesis Condition (A)	1	1363.97	10.680*
Error Between	116	127.68	
Within Ss	118		
Problems (B)	1	.51	.009
A X B	1	1037.87	18.000*
Error Within	116	57.64	

*p < .001

Table 5

Correlation Between Discriminant Scores and Evaluation, Hypothesis Generation and Memory Factor Scores for Subjects Solving the First Four Problems and for Subjects Solving the Last Four Problems

Cognitive Abilities	Problems	
	1-4	5-8
Evaluation	.28	.92
Hypothesis Generation	.97	.37
Memory	-.09	-.12

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